# Pulmonary Balloon Dilation for Valvular and Arterial Stenosis

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*The use of balloon catheters to dilate obstructed vascular lesions represents one of the major advances in cardiology and dates back to 1964 when Dotter and Judkins[3] reported their experience in dilating arteriosclerotic obstructive lesions. Since that time, the technique of balloon dilation has been used extensively for coronary and peripheral vascular lesions but also has been applied to such diverse cardiac lesions as pulmonic stenosis, mitral stenosis, aortic stenosis, aortic coarctation, superior vena caval and pulmonary venous obstructions.*

*Balloon dilation has been used for both valvular and arterial pulmonary stenosis[10]. The purpose of this study is to report on our initial experience in Hawaii with balloon dilation of valvular pulmonic stenosis and also with dilation of peripheral pulmonary artery stenosis due to congenital causes and as a residual postoperative lesion.*

## Introduction

In the field of pediatric cardiology, the first use of a balloon dilation catheter was for valvular pulmonic stenosis[4]. In 1982, Dr. Jean Kan at the Johns Hopkins University School of Medicine used a balloon catheter to successfully dilate the pulmonic valve in an 8-year-old patient. Since that time, there have been other cases reported in the world literature[2,5,6,9,14,15,18,19,21]. As experience accumulated, it became evident that this technique was effective, safe, and had many advantages over surgical valvotomy. Today, balloon valvuloplasty is considered to be the treatment of choice for valvular pulmonic stenosis[8].

Pulmonic stenosis can be divided into valvular, subvalvular and supravalvular stenosis. Supravalvular pulmonic stenosis can be divided into those lesions involving the main pulmonary artery, or either of the main branches or smaller peripheral pulmonary artery branches.

Valvular pulmonic stenosis is one of the more common congenital heart anomalies, occurring in 8% to 10% of patients with congenital heart disease[1]. Supravalvular pulmonary artery stenosis is less common than valvular stenosis and occurs in only 2% to 3% of all patients with congenital heart disease[11].

## Methods

A standard cardiac catheterization and cineangiocardiography is performed to measure the valvular pressure gradient and the diameter of the valve annulus. After heparinization, a balloon catheter is introduced over a guide wire and the center of the balloon is positioned over the valve. The balloon size selected is 20% to 40% larger than the diameter of the valve annulus. The balloon is inflated with dilute contrast material with up to 5 atmospheres of pressure for a duration of up to 15 seconds to achieve the elimination of the "waist" in the balloon which represents the constriction of the balloon by the stenotic valve. During inflation, the arterial blood pressure and electrocardiogram are monitored. After valvuloplasty, the pressure gradient and cineangiocardiogram are repeated.

The same technique is used for peripheral pulmonary artery stenosis except that the balloon sizes are up to 4 times the diameter of the obstructed artery segment and inflation pressures are higher.

## Results

The first case was a 5-year-old girl who was born with Tetralogy of Fallot. She had a large ventricular septal defect and severe valvular pulmonic stenosis requiring a Blalock-Taussig shunt in early infancy to provide adequate pulmonary blood flow. At age 3 years, she underwent total correction of her Tetralogy of Fallot. The pulmonary valve annulus was very constricting and a transannular patch had to be used to enlarge the pulmonary artery.

Several years after her surgery, she developed a significant residual pulmonary obstruction at the site of the transannular patch. At cardiac catheterization, the right ventricular pressure was 139 mm Hg and the gradient across the obstruction was 110 mm Hg.

A 12 mm balloon was selected for the dilation after which the right ventricular pressure was reduced to 86 mm Hg and the gradient was reduced to 58 mm Hg. Followup Doppler echocardiography revealed a persistent 54 mm Hg systolic gradient.

A repeat angioplasty 9 months later using a larger 20 mm balloon failed to reduce the gradient further, and she was referred for surgery. At surgery, the patch was extended to the bifurcation of the branch pulmonary arteries. Postoperative Doppler examination revealed a reduction of the gradient to 36 mm Hg.

The second case was a 16-year-old girl who was born in the Philippines with a large atrial septal defect and severe valvular pulmonic stenosis. After immigrating to Hawaii at age 12 years, she was found to be severely symptomatic.

The atrial septal defect was closed at 13 years of age, and at the same time, a valvotomy was performed.

She was reevaluated by Doppler echocardiography 2 years after surgery and was found to have a significant residual pulmonic gradient. At cardiac catheterization, the right ventricular pressure was 110 mm Hg and the valve gradient was 96 mm Hg. The subvalvular infundibular area was also hypertrophied. An 18 mm balloon was used for the dilation after which the right ventricular pressure decreased to 50 mm Hg and the gradient to 38 mm Hg.

One year later, Doppler echocardiography demonstrated an increase of the gradient to 60 mm Hg. A repeat cardiac

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catheterization confirmed a gradient of 58 mm Hg. Dilation was performed with a 23 mm balloon, reducing the gradient Hg. Three months later, the gradient by Doppler echocardiography remained at 14 mm Hg.

The third case was a 9-year-old boy also born with Tetralogy of Fallot with an absent pulmonary valve and hypoplasia of the pulmonic annulus. At 3 years of age, he had a total correction and a transannular patch was used to relieve the pulmonic stenosis.

Three years after surgery, cardiac catheterization revealed severe residual pulmonic stenosis, and he then had an aortic homograft inserted into the right ventricle with the distal end connected to the main pulmonary artery, bypassing the obstructed annulus.

At 9 years of age, cardiac catheterization identified an obstruction at the junction of the homograft with the main pulmonary artery. The right ventricular pressure was 89 mm Hg and the gradient across the stenosis was 47 mm Hg. After dilation with a 20 mm balloon, the right ventricular pressure decreased to 42 mm Hg and the gradient was reduced to 4 mm Hg.

One year later the right ventricular pressure had again increased to 82 mm Hg and the gradient to 56 mm Hg by catheterization. The patient is awaiting surgical angioplasty; it appears the stenosis was relieved only temporarily by the dilation.

The fourth case was a 14-month-old boy with a combined valvular and supravalvular stenosis. At cardiac catheterization, the right ventricular pressure was 72 mm Hg, the supravalvular gradient was 29 mm Hg and the valvular gradient was 36 mm Hg. Balloon dilation eliminated the valvular gradient and reduced the supravalvular stenosis to 22 mm Hg. It is hoped the small, residual supravalvular gradient will remain so as he grows.

The fifth case was a 7-year-old boy who had his Tetralogy of Fallot repaired at 2 years of age, requiring a transannular patch for a hypoplastic pulmonary annulus. Postoperative Doppler echocardiograms demonstrated a progressive increase in the systolic gradient across the pulmonary outflow tract. At cardiac catheterization, the gradient measured 36 mm Hg. Because of the large diameter of the pulmonary annulus, balloon angioplasty was performed using the double-balloon technique[21]. The 2 balloons were inflated simultaneously and produced a total balloon diameter of 30 mm; the post-dilation gradient was 26 mm Hg.

## Discussion

Several years after the first report by Kan, it became obvious based on the numerous reports from large medical centers throughout the world that pulmonary balloon valvuloplasty was effective in relieving valvular stenosis and is the procedure of choice over surgical valvotomy; it can be carried out safely in regional hospitals. Although not as successful, dilation of peripheral pulmonary artery obstructions also have been accomplished. Recently 5 cases were treated at Straub Clinic & Hospital, the first cases of balloon pulmonary valvulo/angioplasty performed in Hawaii. These cases also demonstrate the different clinical situations in which this technique is applicable; that is, valvular stenosis, congenital pulmonary artery stenosis, and postoperative pulmonary artery stenosis.

The indication for balloon valvuloplasty is the same as for surgical valvotomy; that is, a systolic gradient in excess of 50 mm Hg. There have been recent recommendations to lower this criterion to 35 mm Hg16, primarily because the procedure is relatively noninvasive as compared to surgery, and because an obstruction severe enough to result in a 35 mm Hg gradient might eventually result in irreversible right-ventricular cardiomyopathy.

Complications have been few and are listed in Table 1. Selecting the proper catheter size helps to avoid injury to the vessel wall. Arrhythmias and transient hypotension do occur and are associated with the balloon inflation, but resolve rapidly afterward. Unless there is a significant injury inadvertent to the myocardium, there usually are no other significant arrhythmias.

Cumulative results from some of the larger series reported elsewhere[5,9,15,16,17,18] and comparison with results of surgical valvulotomy[13] are shown in Table 2. The operative mortality is comparable, with valvuloplasty appearing to have the edge over surgical valvotomy when all ages are considered.

Initially when the size of the balloons used was limited to the diameter of the valve annulus, 60% to 70% of patients had significant residual gradients greater than 25 mm Hg6,20. It then was demonstrated that balloon sizes up to 40% larger than the valve annulus diameter could be used safely and results improved with only 7% to 11% of patients having significant residual gradients. The pulmonic regurgitation resulting after either surgical valvotomy or balloon valvuloplasty is usually mild and clinically not significant.

In patients with peripheral pulmonary artery stenosis, approximately 55% of the vessels are successfully dilated with an increase in angiographic diameter by over 50%[8].

Table 3 summarizes the results of Straub's 5 cases.

Valvular stenosis is relieved by the balloon tearing tissue along the path of least resistance by splitting the fused commissures or by tearing through the cusp itself, and sometimes by avulsion of the cusp from the annulus[20]. In our 2 cases with valvular stenosis, the gradients across the valve were significantly reduced and postvalvuloplasty cineangiocardiograms demonstrated increased systolic valve opening.

Dilation of congenital peripheral pulmonary artery stenosis is probably accomplished in much the same manner as dilation of coarctation of the aorta; that is, by tearing of the intima[7]. However restenosis can occur with accumulation of fibrous tissue in the healing process. In our patient with a combination of valvular and supravalvular stenosis, the latter obstruction was partially relieved by dilation.

There are few reports of results following dilation of postoperative residual pulmonary artery stenosis. In our first patient, who had repair of a Tetralogy of Fallot and who developed a residual stenosis at the area of the transannular patch, tearing fibrous tissue within the patch may have been the mechanism responsible for the partial reduction of the obstruction. However, the discrepancy in size between the dilated proximal and narrow distal main pulmonary artery was not remediable to further balloon dilation and the patient required further surgery.

The patient with the aortic homograft obstruction appears to have had only a temporary successful result. In his situation, the stenotic area may have been stretched but gradually recoiled to its previous state.

Repeat catheterization of some of these patients in the future will enable us to evaluate the long-term results of balloon dilation and the ability of this technique to permanently relieve obstruction of pulmonary valves and arteries.

## Summary

Five patients with a combined experience of pulmonary valvular stenosis (2 cases), congenital supravalvular stenosis (1 case), and postoperative residual pulmonary artery stenosis (3 cases) are presented along with the results of balloon dilation of these lesions. Balloon dilation was successful in the 2 valvular lesions, partially successful in 1 patient with supravalvular stenosis, and helpful in 1 out of 3 patients with postoperative pulmonary artery stenosis. Balloon dilation is the treatment of choice in valvular pulmonic stenosis and may be helpful in congenital and acquired pulmonary artery obstructions.


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**TABLE 1. Potential complications of balloon dilation**

1. Rupture of the pulmonary artery.
2. Contusion to the right ventricular outflow tract.
3. Transient hypotension.
4. Ventricular ectopic beats during balloon inflation.

**TABLE 2. Comparative results of surgical valvotomy and balloon valvuloplasty for valvular pulmonic stenosis**

| | Surgery | Valvuloplasty |
|---|---|---|
| Mortality | < 10% < 2 yrs<br>< 0.5% > 2 yrs | < 0.5% all ages |
| Residual gradient < 25 mm Hg. | 81% | 89 - 93% |
| Residual pulmonic regurgitation | 50% | 20% |

**TABLE 3. Results of balloon dilation**

| | Before | | After | | | |
|---|---|---|---|---|---|---|
| | RV Press MM HG | PA GRAD MM HG | RV Press MM HG | PA Grad MM HG | RV Press Reduction % | PA Grad Reduction % |
| Case #1 (A) | 139 | 110 | 86 | 58 | 38 | 47 |
| | 105 | 58 | 94 | 54 | 10 | 7 |
| Case #2 (V) | 110 | 96 | 50 | 38 | 55 | 60 |
| | 71 | 58 | 32 | 14 | 55 | 76 |
| Case #3 (H) | 89 | 47 | 42 | 24 | 53 | 49 |
| (H) | 82 | 56 | | | | |
| Case #4 (V,S) | 72 | 36 v<br>29 s | 46 | 0 v<br>22 s | 36 | 100 v<br>24 s |
| Case #5 (A) | 58 | 36 | 46 | 26 | 21 | 28 |

A= artery H= homograft
V= valve S= supravalvular